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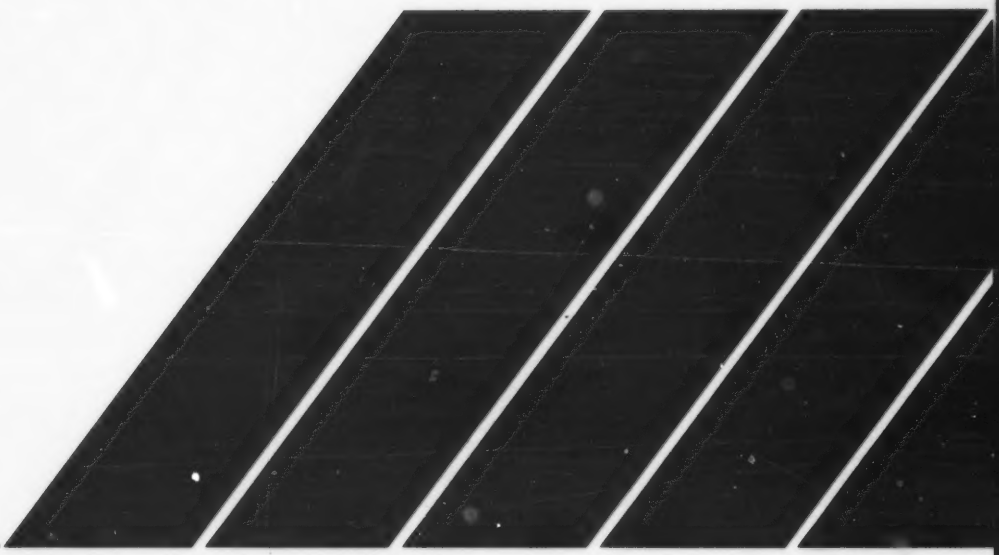
PERFORMANCE TESTING OF THE 90-kW BIOBLAST WOOD CHIP COMBUSTION UNIT



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PERFORMANCE TESTING OF THE 90-kW BIOBLAST WOOD CHIP COMBUSTION UNIT

PREPARED FOR:

Efficiency and Alternative Energy Technology Branch
Energy, Mines and Resources Canada
Ottawa, Ont.
DSS Contract No. 23440-0-9514
September, 1991

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38pp

92-02854/

CITATION

LeMay, C., I.R.T.A. *Performance Testing of the 90-kW Bioblast Wood Chip Combustion Unit. DSS Contract No. 23440-0-9514.* Efficiency and Alternative Energy Technology Branch, Energy, Mines and Resources Canada, Ottawa, Ontario. 1991 (33 pp.)

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NOTE

Funding for this project was provided by the Federal Panel on Energy Research and Development, Energy, Mines and Resources Canada.

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Catalogue No. M91-7/162-1991E
ISBN. 0-662-19315-6

Summary

A 90-kW Bioblast wood-chip-fired preheater was tested at IRTA to CSA Performance test standard B415. The preheater burned most fuels far below the 0.096 g/MJ particulate emissions requirement. It had no problems handling chips and sawdust in the 40% moisture content range. The feed system delivered all fuels with reasonable consistency. Tests on an alternative bin design proved inconclusive.

The two heat exchange boilers with which the burner was tested were radically different. The primary intention was to compare a vertical-tube boiler with a horizontal-tube boiler, especially with respect to ash accumulation on heat exchange surfaces. Because of the multiple differences, no clear comparison was possible. The Parrsboro boiler was designed exclusively as a vertical-fire-tube pressurized boiler heat exchanger for the Bioblast preheater. It performed very well at the high end of the Bioblast output. Its heat exchange was over capacity for the low end combustions. The Maco boiler is a horizontal water-tube non-pressurized boiler which can serve either as a heat exchanger for the Bioblast stoker or as a roundwood combustion unit. It has a less sophisticated heat exchanger design but on a farm, its capacity to burn roundwood is a very attractive feature. Its heat exchange capacity was satisfactory at the medium and low end of the preheater's capacity, with large losses in efficiency at the high end.

Résumé

L'IRTA a soumis un brûleur à copeaux de bois Bioblast, d'une puissance de 90 kW, à des essais selon la norme CSA B415. L'appareil a réussi a brûler presque tous les combustibles à un niveau significativement inférieur à la limite d'émissions particulaires de 0.096 g/MJ recommandée. L'appareil s'est avéré très fonctionnel pour des copeaux et de la sciure de bois aux environs de 40% d'humidité calculé sur une base sèche. Le convoyeur réussissait à fournir des copeaux à un taux régulier. Des essais sur une trémie de conception différente se sont avérés inconcluants.

Deux chaudières ont servi d'échangeurs de chaleur dans le but de comparer la performance d'une chaudière à tuyaux horizontaux contre une autre à tuyauterie verticale, principalement à ce qui a trait à l'accumulation de cendres. Malheureusement trop d'autres variables n'ont pas permis la comparaison par rapport aux cendres. La chaudière Parrsboro a été conçue comme échangeur de chaleur à tuyaux verticaux pour le Bioblast. Les tuyaux verticaux servent de conduits aux produits de combustion. La chaudière Maco est une chaudière pouvant servir à brûler du bois rond aussi bien qu'à être utilisée comme échangeur de chaleur. Les tuyaux horizontaux servent de conduits pour l'eau, les flammes étant à l'extérieur. La capacité d'échange de chaleur du Parrsboro est nettement dans la zone d'opération maximale du Bioblast. Le Maco est plutôt conçu pour répondre à une opération du brûleur à taux moyen et bas.

Nous avons recommandé plusieurs améliorations de conception de l'appareil, aussi bien du côté du mécanisme de transport du combustible que du côté de la combustion elle-même. Plusieurs de ces améliorations sont déjà incorporées dans les appareils fabriqués à l'heure actuelle.

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Appendix 1 Bioblast 2 data sheet
Appendix 2 Pressure loss across the Parrsboro boiler: data provided to the designer and manufacturer.

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Note: all fuel moisture contents are expressed in wet basis i.e. **mcwb**.

$$\text{Moisture content percent} = \frac{\text{weight of water}}{\text{weight of wood plus water}} \times 100$$

1.0 BACKGROUND TO STUDY

There are vast quantities of wood available which are unsuitable for lumber or even pulp production but which are eminently suitable for transformation into fuel chips, often at low cost. Moreover, environmental authorities are now prohibiting the stockpiling of sawmill by-products such as bark and sawdust. Combustion of this material in particulate-fuel burners to provide space and process heat would convert a disposal problem into a means to reduce energy costs.

A few years ago most particulate fuel burners in the small-commercial range (50 to 300 kW) were European. While Scandinavian woodchip-fired appliances were found to burn waste wood much more cleanly than conventional roundwood burning appliances, they were manufactured to European specifications and quite expensive. A Canadian initiative was needed.

A P.E.I. dealer in Scandinavian appliances and an Ontario manufacturer cooperated to develop a Canadian pre-heater, the Bioblast. To date there are over thirty Bioblast installations in the Maritimes which seem to perform well using softwood chips and sawdust. Several Ontario dealers expressed interest in the Bioblast but no technical data were available. It is in this context that EMR retained IRTA for performance testing of the appliance.

This paper reports on a modified version of the unit which we will call Bioblast-2. A first higher-output version of the pre-heater had already been tested under a different contract with excellent results.

2.0 OBJECTIVES

The objectives of the work were

- to obtain emission, output and efficiency data for the Bioblast pre-heater
- to determine acceptable fuel types and moisture contents
- to assess the overall electrical and mechanical reliability of the pre-heater and recommend design improvements
- to assist the manufacturer in the preparation of a reliable data sheet for the appliance

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NOMENCLATURE

In order to facilitate comprehension of the terminology used in this report, the following definitions[1] are presented.

Stoker: a mechanical device that feeds particulate fuel into a combustion chamber. The stoker requires insertion into a heat exchanger which is usually a warm air furnace or boiler. A stoker may include a grate, retort or combustion bowl. Combustion takes place inside the structure of the heat exchanger.

Preheater: an appliance which includes a stoker and a free standing, or a least separate, combustion chamber. The stoker supplies particulate fuel to the combustion chamber where normally the fuel is burned completely. The preheater requires connection to a heat exchanger which can, in some cases, be a suitably modified warm air furnace or boiler. The connection is provided by a short, refractory-lined tunnel. When a preheater is pushed to maximum output, there may be insufficient residence time in the combustion cell to allow complete combustion, in which case secondary combustion may be completed in the refractory-lined tunnel.

[1] Based on terminology presented by Prof. C. A. Short at the Chip Combustion Workshop sponsored by E.M.R., hosted by IRTA in Rockland, Ontario on June 7 and 8, 1988.

3.0 DESCRIPTION OF APPLIANCES

3.1 Bioblast pre-heater (Figure 1)

The Bioblast is a Canadian-built preheater. The appliance consists of a chip bin, a gearmotor-operated chip delivery system and a combustion chamber. All operations are regulated from a control panel.

We rated the Bioblast-2 at 90 kW output[2]. The design of the air supply, both from a perspective of power and distribution, does not allow a higher output with chips without fuel overfeed. The previous version of the Bioblast managed to attain 130 kW output but at that rate of burn, some components reached excessively high temperatures.

The surge bin is rectangular at the top and tapers to a circular shape at the bottom. Bins of different capacities are available. The bin supplied with this unit had a volume of 1.7 cubic metres. To prevent fuel bridging, an agitator rotates inside the bin; it consists of a horizontal 9-cm shaft, fitted with a large vertical wheel and 6 triangular protruding arms. This mechanism is driven by the auger whose flights intermesh with the teeth of the vertical wheel.

A 220-volt 3/4 hp[3] gearmotor drives the fuel auger. The 10-cm diameter auger rotates inside a 14 cm-wide U-shaped tube to transport fuel to the combustion chamber.

Fuel feed rates are changed by adjusting a timer for motor on-times and motor off-times. Both may be varied from 1 to 100 seconds. The demand and hold-fire modes are regulated by two distinct but identical sets of controls. Combustion air is supplied by a fan. The combination of underfire and overfire air is regulated by two baffles. Identical controls allow fan speed adjustment for both normal operation and hold-fire. The system is switched from the demand mode to the hold-fire mode by the boiler thermostat.

The rectangular combustion chamber is lined with refractory brick. The combustion chamber has a large refractory-lined steel cover. A smaller inspection port is fitted in the centre of this large cover.

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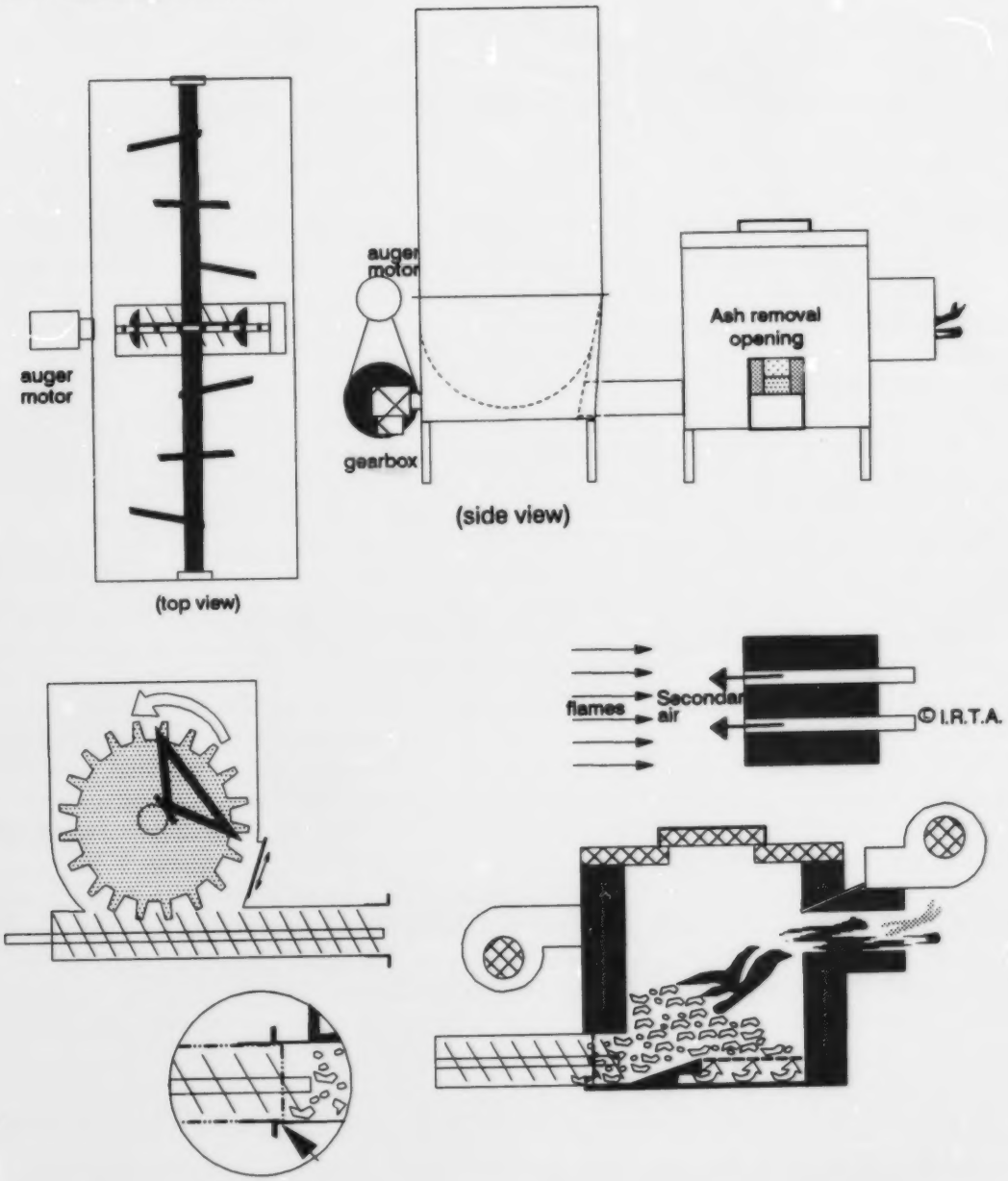
[2] At maximum output, with low-moisture hardwood chips, we obtained 99 kW.

[3] A 1/2 hp motor is sufficient when using good quality softwood chips.

Figure 1. Bioblast Preheater



3.2 Parrsboro vertical-fire-tube boiler (Figure 2)

The Parrsboro boiler was designed expressly as a heat exchanger for the Bioblast. A square opening at the base of the boiler allows insertion of the combustor tube from the Bioblast.

The boiler is 2.3 metres high and has a 1 square metre base, taking up very little floor space. An inspection door faces the combustor tube opening. Ash can be removed by pulling out an ash pan accessible by a door on either side of the boiler. Hot gases from the combustor tube enter the plenum of the boiler directly under a series of 109 fire tubes. These tubes are 880 mm long with an inside diameter of 38 mm. Optional turbulators (corrugated strips of metal) can be installed inside the fire tubes to increase turbulence and thus heat transfer if the boiler is otherwise under capacity relative to the preheater.

The top of the boiler is fitted with a cover for easy access to the fire tubes. The cover is provided with four 250-mm flue collar outlet locations.

3.3 Maco jacket-type boiler[4] (Figure 4)

Many Bioblasts have been installed in conjunction with Maco boilers. The Maco is a jacket-type boiler with horizontal water tubes. It is designed for burning roundwood and was fitted with a side adapter for the Bioblast preheater. The boiler is 1.2 metres wide, 1.7 metres long and 1.5 metres high. It has a combustion chamber volume of 0.9 cubic metre and can accept logs 1.3-metres long.

Eleven 9-cm outside-diameter water tubes form the top of the combustion chamber and run its length. Angle irons positioned on the water tubes form the boiler's baffle system. An inspection door provides access above the baffles and water tubes. The boiler has a by-pass damper to facilitate lightup.

A manifold at the top of the boiler allows for hookup of the various hot water pipes and gauges.

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[4] Comments and data on the Maco boiler are from a previous contract.

Figure 2. The Parrsboro Vertical firetube Boiler

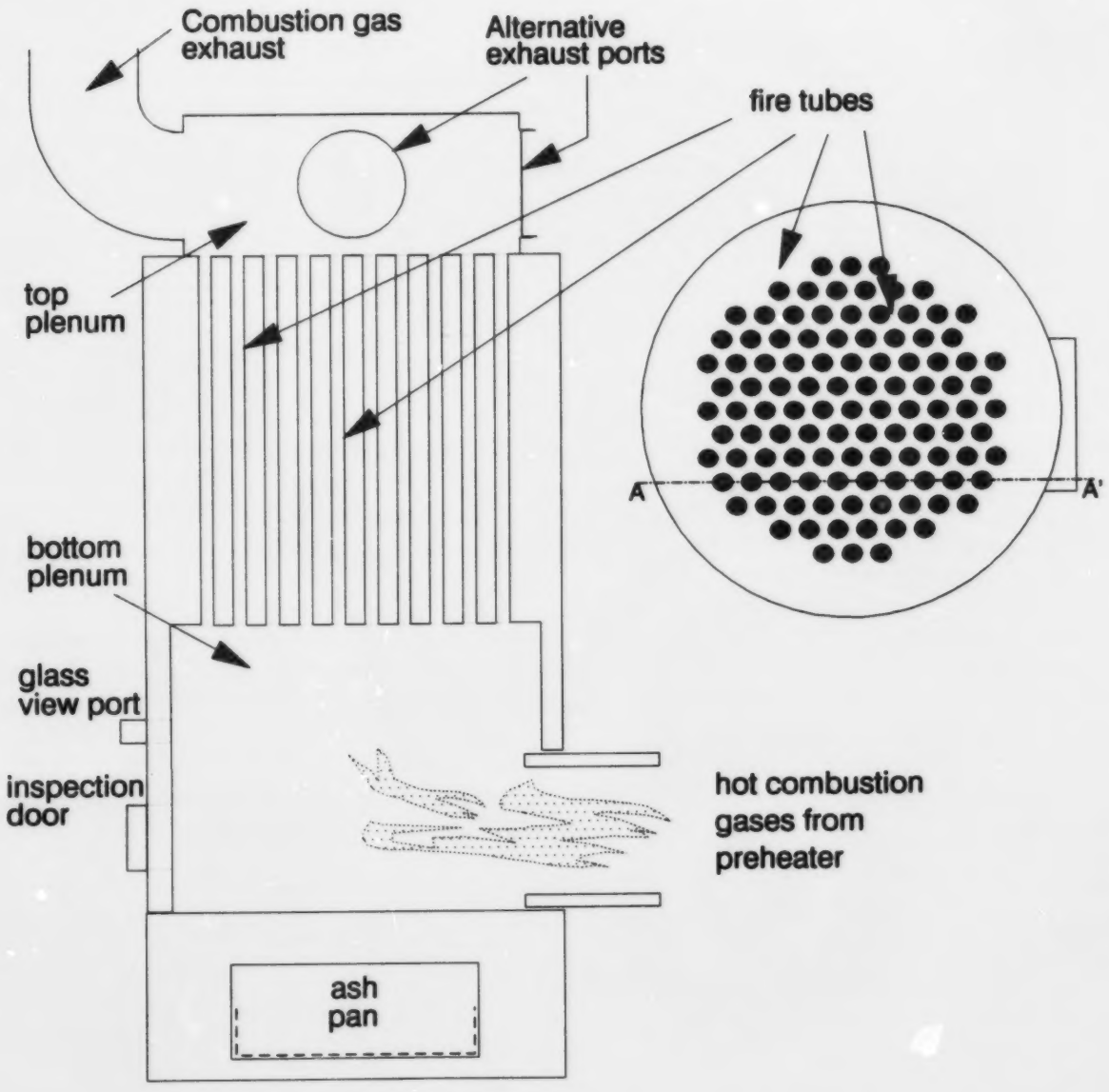
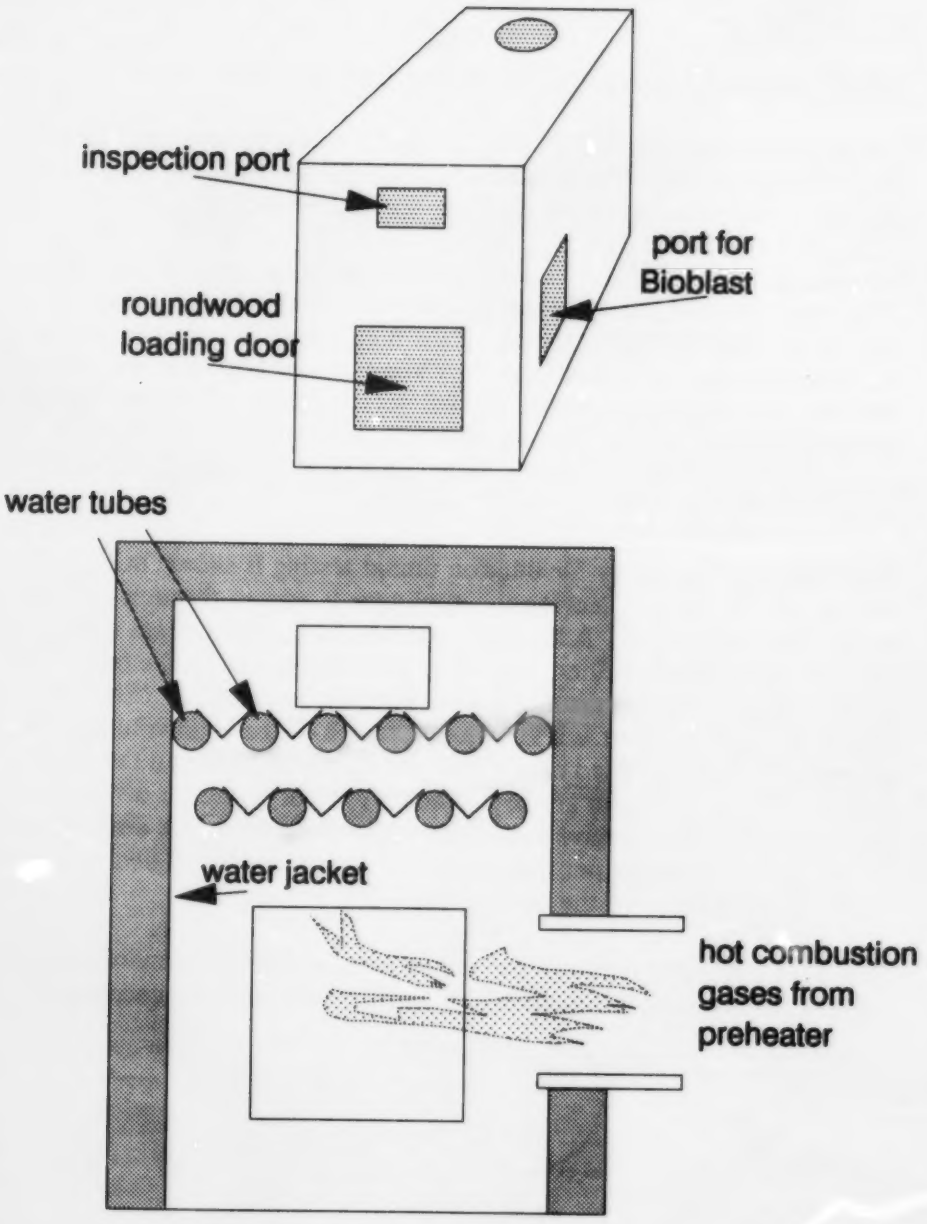


Figure 3. The Maco Boiler



4.0 METHODOLOGY

4.1 Test protocols

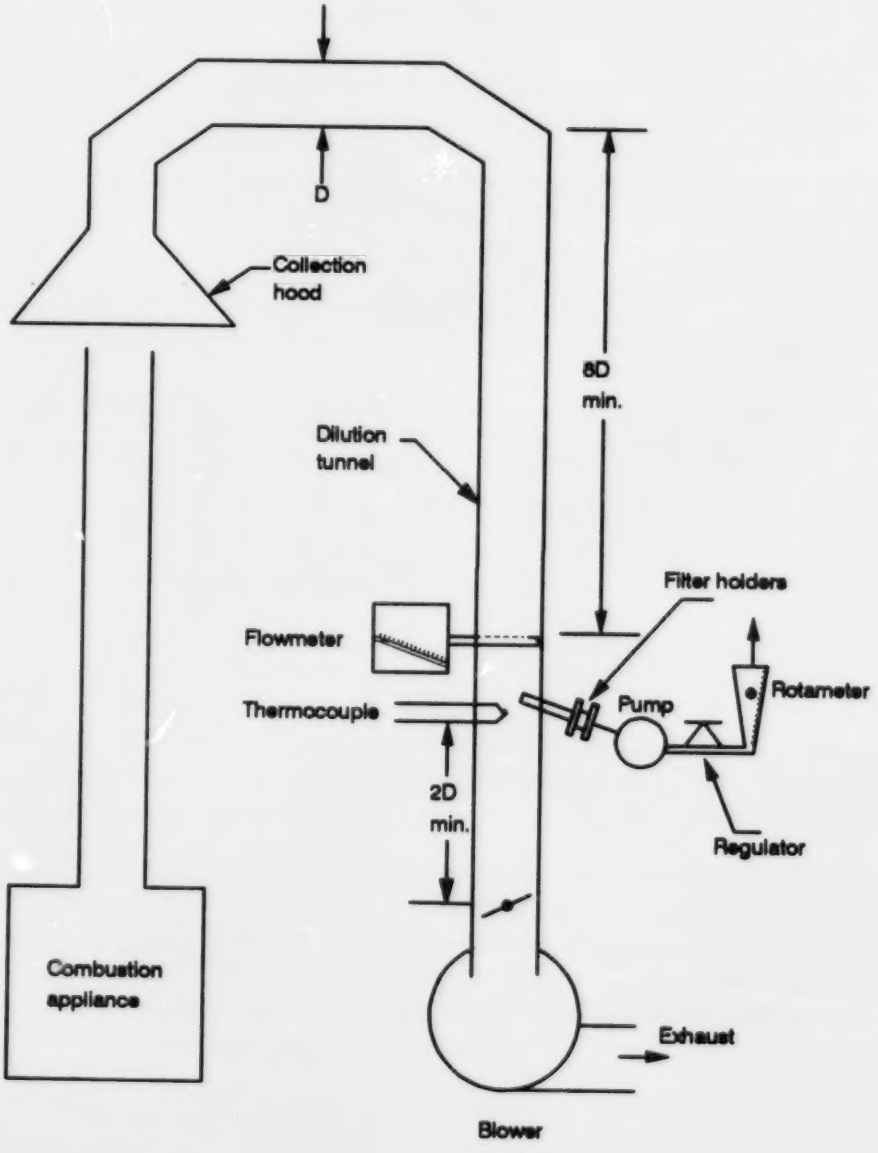
i) B415 testing for efficiency, output and emissions

The dilution tunnel procedure used for performance testing was taken from the **CSA B415 M1986 standard "Performance Testing of Solid-Fuel-Burning Appliances".** This standard describes a test procedure for calculating the overall efficiency and measuring the particulate and carbon monoxide emissions levels of free-standing woodburning appliances at various firing rates. The procedure involves the burning of a standard wood charge. Flue gas temperatures and percentages of CO_2, CO, O_2, and the steadily decreasing weight of the fuel charge are recorded. The test involves the calculation of the chemical energy loss (smoke) and heat loss (hot gases) up the chimney and the measurement of the total amount of particulates generated by incomplete combustion. The dilution tunnel procedure is relatively easy to perform and is very suitable for in-plant product development testing. For details of this test procedure, refer to the CSA B415 standard.

The apparatus necessary for dilution tunnel testing is shown in Figure 4. The total volume of the flue gas leaving the appliance is routed through a tunnel where it is mixed with ambient air. A known proportion of the diluted gas flow is then pumped through a pre-weighed filter. The filter is re-weighed after the burn. The difference is the weight of the particulate matter trapped by the filter. Since the sample that passes through the filter is a known proportion of the total volume, the total weight of the particulates emitted can be calculated. The weight can then be averaged over time to give a reading in grams per hour (g/h) or it can be divided by the mass of the dry wood burned to give a reading in grams of particulate emissions per kilogram of fuel (g/kg) or grams per megajoule (g/MJ) of calculated heat input based on the higher heating value of the as-fired fuel.

The B415 emissions data can be related precisely to U.S. Environmental Protection Agency (EPA) data, although use of a correction factor is necessary.

Figure 4. Apparatus Used for Dilution Tunnel Tests[5]



[5] Taken from the CSA B415 standard "Performance Testing of Solid Fuel Burning Appliances".

ii) Modifications to B415 procedure for testing preheaters

The CSA B415-M1986 test procedure was designed for solid-fuel-fired (roundwood) appliances, and several modifications are required for testing a preheater.

- different burn rates were obtained by modifying the feed rate.
- the particulate fuel in the bin was maintained at a constant level throughout the tests.
- the combustion air fan was set for optimum CO and CO_2 levels in combustion gases. This is the setting a trained technician would try to obtain in the field when using an instrumented appliance. The blower baffles for overfire and underfire air were adjusted once for each fuel type.
- the two particulate fuels were tested at three moisture contents levels as opposed to the single 18% moisture content used with the roundwood-fired stoves.
- constant fuel composition was used in the B415 calculations as opposed to the variable composition used when dealing with roundwood.

4.2 Fuel handling, storage and conditioning

i) Fuel types

The Bioblast was tested with chips and sawdust. The chips were purchased from a sawmill. They were hardwood of a good uniform quality (single species, no bark) but had some long splinters. The sawdust was obtained from a sawmill and was of good uniform quality but it also had some long splinters as well as large pieces of bark.

ii) Conditioning

For testing, each fuel was to have moisture contents of approximately 15, 30 and 45% mcwb. To obtain the lower moisture contents each load of fuel had be dried inside for at least one week. At the other end of the moisture spectrum, since it is difficult to raise hardwood moisture content to 45%, ice-laden chips were used, such as those that would have been stored outside, uncovered.

4.3 Emission testing

i) Feed tests

Feed tests were performed to measure the continuous fuel feed rates for each fuel type. During these tests, the fuel delivery tube was not attached to the combustion chamber. All the fuel transported by the auger over a 5-minute interval was weighed. An average was taken over 3 to 5 tests. Feed tests were performed for each series of combustion tests, i.e. when changing fuel type or moisture content.

ii) Burn rates (on/off times)

Burn rates were measured as on/off proportions of the continuous rate. After selecting an appropriate setting, both "on" and "off" periods were accurately timed. The actual burn rate was then calculated as

$$\text{burn rate} = \frac{(\text{on-time})}{(\text{on-time}) + (\text{off-time})} \times \text{continuous feed rate}$$

where on-time is the time the auger is running
off-time is the time the auger is not running.
continuous feed rate is the rate at which fuel is moved when the motor runs continuously.

As for standard B415 tests, rates quoted in the report are dry rates, i.e. the total mass of fuel minus the weight of moisture. From these dry rates, we were able to calculate the energy input.

iii) Sources of error and counter-measures

The major source of error in these tests was feed rate variability due to partial, temporary blockage of the fuel delivery path. These blockages were sporadic and the only remedial measure was to maintain a constant level in the feed bin and use a poker to prevent the formation of "rat holes".

Figure 5 is a schematic of the test installation. Several checks were performed every ten minutes during testing to reduce errors:

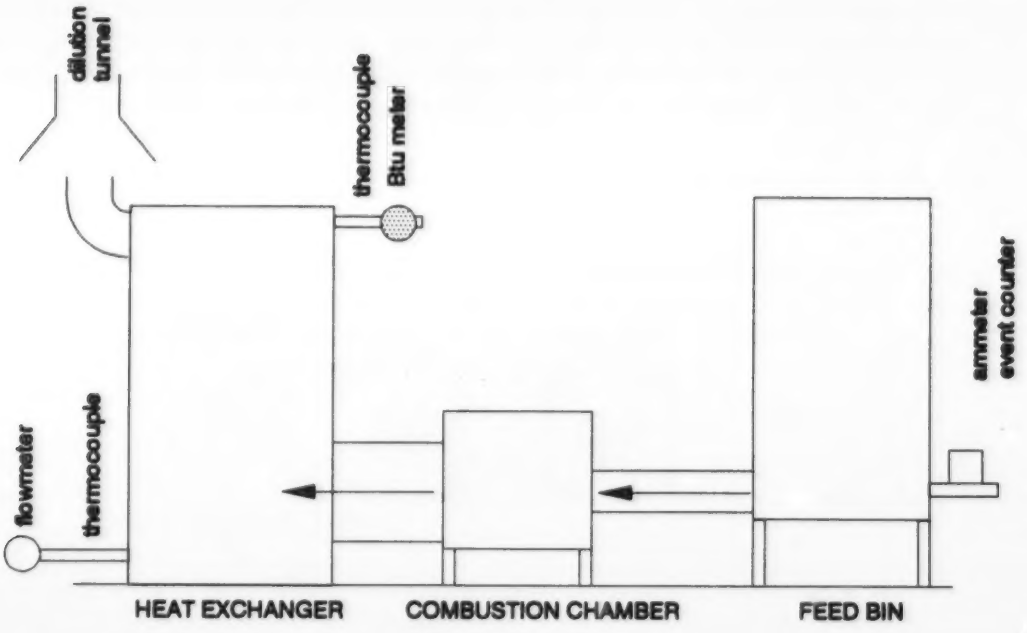
- to verify the accuracy of the Btu meter, a flow meter recorded water flow through the boiler, and thermocouples recorded intake and output temperatures. The calibration of both the Btu meter and the flow meter were verified against the filling rate of a barrel of known volume.

- a run-time meter wired to the auger motor totalled the time the gearmotor operated during each test, providing a double check for the actual total feed time over the combustion period.

- an event counter totalled the number of auger-motor cycles during a test.

- an ampere meter was used to measure the auger motor's amperage draw in order to alert us to any blockage. An unusual increase in current drawn by the motor signalled a blockage.

Figure 5. Test Installation



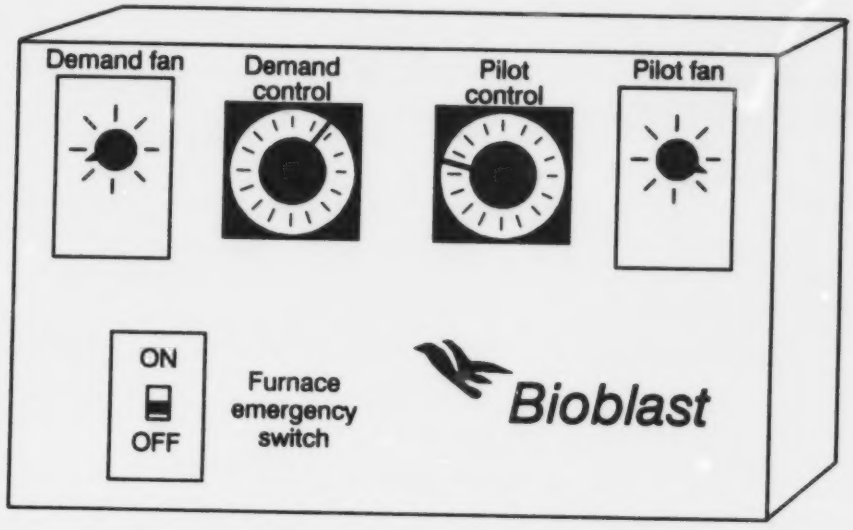
dryer, precision balance (0.1 mg)	drying oven, triple arm balance	weigh scale, precision timer
particulate weight measurement	fuel moisture measurement	fuel feed measurement

5.0 OBSERVATIONS

5.1 Electrical control panel

The electrical control box consists of two totally independent circuits, one controlling the demand sequence, the other the hold-fire sequence. Each circuit controls the cycling of the auger, i.e. on-time from 1 to 100 seconds and off-time from 1 to 100 seconds. Each circuit has also a variable speed control for the combustion air blower.

Figure 6. Electric control panel



5.2 Fuel flow

Even the best combustion chamber will not operate without fuel. The chip handling system is at the heart of any stoker or pre-heater.

This new version of the Bioblast has increased clearances for the agitating wheel. It also features a delivery tube that slips inside the fuel entry port on the combustion chamber, thus eliminating alignment problems. We experienced no fuel blockage. We eliminated the screeching noise dry fuel sometimes produces against the metal by slightly oiling the sides of the delivery tube once a week.

5.3 Temperatures of combustion chamber outer walls.

The outer shell of the combustion chamber reached high temperatures, 151°C for the sides and 230°C for the bottom. A radiation shield would help prevent possible burns to the user as well as improve fire protection.

The small steel inspection port on top of the combustion chamber reached 465°C and warped. Design should be modified to accommodate high temperatures and the top should be better insulated.

5.4 Ash cleanout

Removing ash from the combustion chamber involves the removal of a piece of refractory by means of a poker which can be inserted into a hole in the piece. This can be done even when the system is hot, although it is easier when the system is cool.

5.5 Burnback along feed tube

We experienced burnback of fuel in the feed tube when using the drier chips. The douser takes care of burnback but a drain plug would be a definite asset to rapidly drain excess water after the feed tube has cooled.

5.6 Comparison of boilers used as heat exchangers

i) Heat exchange

The Parrsboro[6] vertical-tube boiler, used with or without turbulators, provided better heat exchange than the Maco in spite of the Parrsboro having a smaller volume. Because of its high heat exchange capacity, the Parrsboro can reduce stack temperatures below the dew point if the Bioblast is fired in its lower output range, especially on hold-fire with high-moisture fuel and a cold chimney. Because the Maco is a poor heat exchanger in the upper firing rates of the Bioblast, it would be advantageous to make sure the system is operated at a rate only slightly higher than demand during call for heat, in such a way as to operate almost continuously (practically no hold-fire). This would maintain it closer to its maximum efficiency.

[6] See appendix 1 for data provided to the designer and manufacturer of the Parrsboro boiler.

ii) Maintenance

The Parrsboro boiler vertical tubes would require close to a 12-foot ceiling to clean the fire tubes if rigid brushes were used, but with flexible brushes, a 10-foot ceiling would be adequate. Cleaning entails a complete shutdown of the system and the removal of the cover and turbulators (when they are used). The Maco boiler requires 6 feet of free space in front of the door to remove any ash deposit on top of the eleven water tubes.

We estimate that cleaning the Parrsboro boiler would take an hour's maintenance, including dismantling, brushing (109 tubes) and re-assembly. The Maco requires only 10 minutes to clean. The heat exchange efficiency needed in the 90 kW range would easily justify the extra time spent on maintenance. Cleaning frequency is difficult to estimate; bi-monthly cleaning might be reasonable both on the Parrsboro and on the Maco. A horizontal **fire-tube** boiler with 109 tubes would probably need more than twice this frequency when used with this type of fuel.

6.0 TEST RESULTS

6.1 Particulate emissions

Particulate emission levels for wood chip and sawdust fuels are shown in Figures 7 and 8.

i) for wood chips:

Particulate emissions for wood chip combustion using the Parrsboro boiler as a heat exchanger, are well below the B415 recommended limit of 0.096 g/MJ except for the high-moisture content, ice-laden chips[7].

ii) for sawdust:

Particulate emissions for sawdust combustion were low, except at very low burn rates such as those which might occur during hold-fire.

To obtain these low emission rates for each particular fuel, the operator must first adjust the fuel feed rate to match the demand as closely as possible, with a very slight excess. He must then adjust the speed of the combustion air blower as well as the ratio of underfire air to overfire air. This ratio is established by adjusting the angle of the two control dampers: each fuel will necessitate a modification of this setting. CO and CO_2 meters are necessary for best adjustment, but a good adjustment can be made without instrumentation, by first lowering the fan speed to a point where smoke from the stack becomes visible. The operator then modifies the overfire and underfire air ratio and readjusts fan speed as described above. This procedure is repeated until the lowest possible fan setting is attained. When modifications to overfire and underfire combustion air do not reduce stack smoke any further, the blower speed is slightly increased to the point where the smoke disappears. This should reduce excess air to a minimum.

As can be seen from the following graphs, with good adjustment, 32% mcwb chips can have a particulate emission level close to 0.02 g/MJ, more than 4 times lower than the proposed limit. From these and previous tests, we have found that emissions in this range can be maintained with chips in the 38 to 40% range.

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[7] See note 3.

We reduced the emission level of these chips to acceptable levels by adding 10% automobile tire "chips" to these wet chips. For these tests, the tires were "chipped" on a shop shear.

Figure 7.

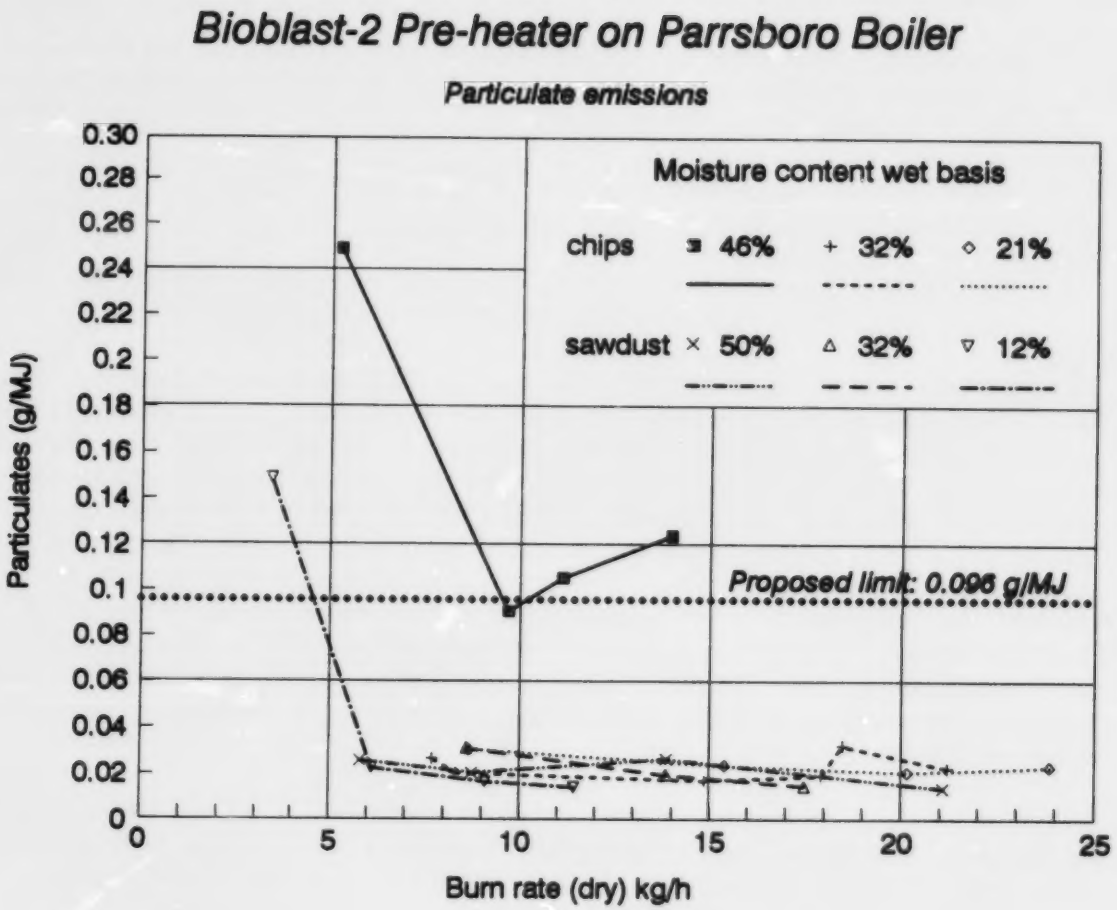
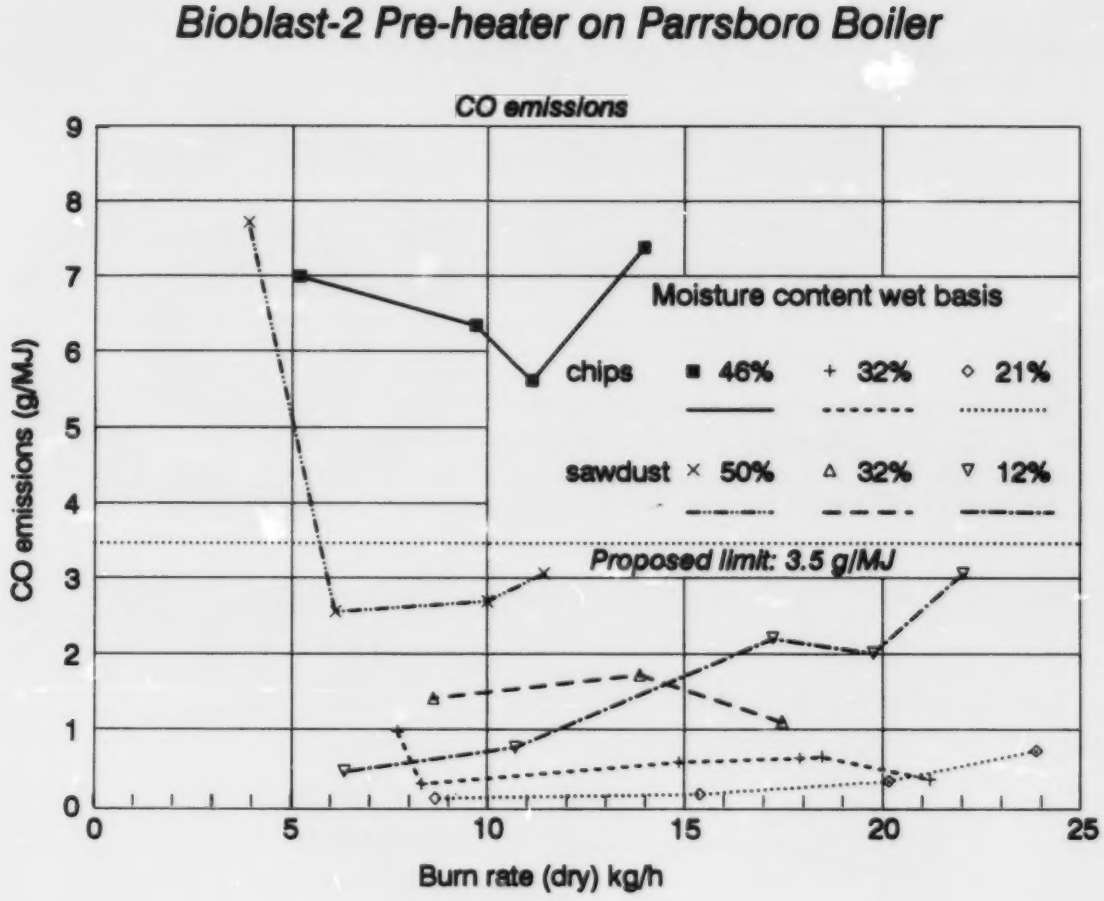

Bioblast-2 Pre-heater on Parrsboro Boiler
Particulate emissions
Moisture content wet basis
chips 46% 32% 21%
sawdust 50% 32% 12%
Proposed limit: 0.096 g/MJ
Particulates (g/MJ)
0.30
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
Burn rate (dry) kg/h

Figure 8.


Bioblast-2 Pre-heater on Parrsboro Boiler
CO emissions
CO emissions (g/MJ)
Burn rate (dry) kg/h
Moisture content wet basis
chips ■ 46% + 32% ◇ 21%
sawdust × 50% △ 32% ▽ 12%
Proposed limit: 3.5 g/MJ
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25

6.2 System output and efficiency

In this series of tests, we measured efficiency and output using two distinct methods. The first method consisted of measuring the amount of fuel energy input and the amount of heat escaping through the stack; the difference is the heat extracted by the system. We have called the ratio of the heat extracted by the system over the fuel energy input the "B415 efficiency".

$$\textit{Energy input} = (\textit{dry fuel feed rate}) * (\textit{higher heating value})$$

$$\textit{Energy output B415} = (\textit{Energy input}) - (\textit{chimney energy loss})$$

$$\textit{B415 Efficiency} = \frac{\textit{Energy output B415}}{\textit{Energy input}}$$

The second method consists of measuring the amount of heat actually delivered by the hot water. This is measured by two independent methods, each of which measures water flow and the difference in temperature between incoming and outgoing water. This efficiency ("Btu-meter"[8] efficiency) involves the following equations:

$$\textit{Energy input} = (\textit{dry fuel feed rate}) * (\textit{higher heating value})$$

$$\textit{Energy output} = \textit{Btu meter reading}$$

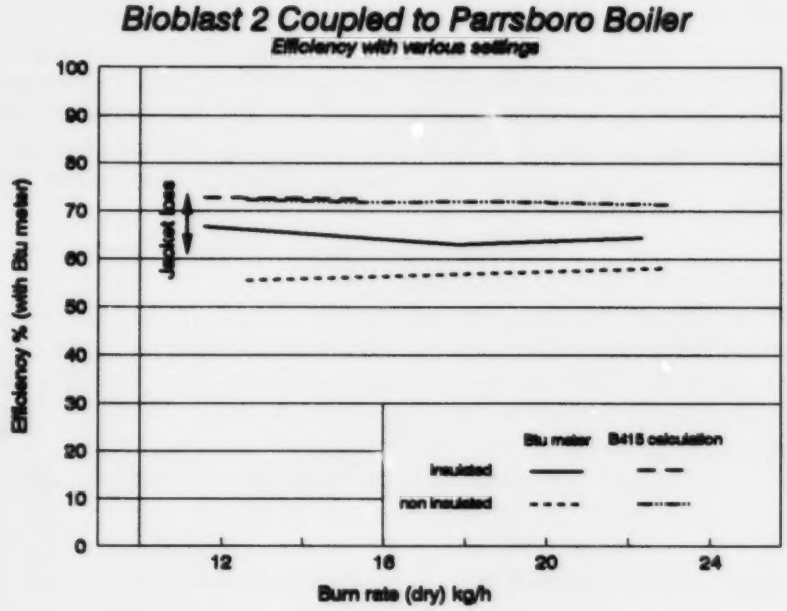
$$\textit{Btu-meter efficiency} = \frac{\textit{Energy output as per Btu-meter}}{\textit{Energy input}}$$

[8] The "Btu meter" is an instruments which integrates data from a built-in flow meter coupled to two temperature sensors. It was continuously backed-up with an independent flow meter and a set of thermocouples.

Figure 9 illustrates the results of these two methodologies on two series of tests using 35% mcwb wood chips. The discrepancy between the two sets of curves[9] is the amount of heat generated by the system, maintained inside the "room" but not transferred to the water. This "jacket loss" is radiated by both the preheater and by the boiler itself. Insulating the preheater combustion chamber shows a worthwhile improvement. The jacket loss for the non-insulated combustion chamber was close to 14 percentage points as opposed to approximately 10 percentage points for the insulated combustion chamber. The surface temperature of the top boiler plenum was relatively high: if jacket-loss heat is not required in the furnace room, it would probably be advantageous to insulate the top and use this heat to increase stack temperatures, thus generating a better draft and lowering the chances of condensation. Alternatively, if additional space heat is required beyond the furnace room during a portion of the year, a heat pump could be installed in the furnace room.

Jacket loss = (Efficiency B415) - (Efficiency Btu-meter)

Figure 9. System efficiency and jacket loss



[9] When evaluating this comparison, measurement errors must be taken into account.

Maximum output obtained:

The maximum rate of burn at which we operated the system during performance testing was 24 kg/h (dry rate) with 21% mcwb chips. The average output over one hour at this firing rate was 335 MJ/h (93 kW). With 32% mcwb chips, we obtained a burn rate of 21 kg/h (dry rate) with an output of 283 MJ/h (79 kW). With 46% mcwb chips, the maximum dry rate was 14 kg/h with an output of 171 MJ/h (48 kW). We found no evidence of deterioration of combustion chamber materials in the 90 kW range.

6.3 Fuel delivery and bin design

i- Problems with existing bin design

The existing bin design results in occasional blockages with hardwood chips. The system reduces blockage by continuously bringing the chips that miss the delivery tube exit back to the top of the pile. This is done by the mixing wheel. Most chips that resist this movement are sheared into smaller pieces by brute force. Large hardwood chips may offer enough resistance to stop the motor instead of shearing.

ii- Current relevant research

Energy, Mines and Resources has contracted out research into the development of improved chip delivery mechanisms, mainly to BC Research Council. The main thrust of the results supports the use of the non-compacting feeder (NCF). No simple version of the NCF has yet been fabricated for use with small-commercial chip burning systems. This research has also produced other information that has been partially integrated into the new design discussed below.

iii- Redesign of the Bioblast bin (Figure 10)

(a) Objectives for a new bin design included the following

- a reduction in the motor capacity required
- lower fabrication costs due to:
  - simplified bin shape
  - removal of the agitator mechanism

(b) Problems encountered with the new design included:

(i) restricted choice of augers flights

According to the manufacturer, auger flights come mainly in 4"-diam., 2"-pitch; 4"-diam., 4"-pitch; 6"-diam., 3"-pitch; 6"-diam., 6"-pitch; etc... As auger diameter increases, shaft diameter also increases. It is always possible to obtain flights of a specified inside and outside diameter with a given pitch provided the order is for 1000 feet or more. It is also possible to find other flights designed with thinner material, mainly for agricultural purposes; grains are much less abrasive and flow more easily.

Faced with this, the manufacturer managed to obtain reasonable 2" and 4" flights and had to improvise the remainder of flights, with poor success. To all intents and purposes, the feed screw had two auger flight pitches, 2-inch for the first 34 inches and 4-inch for the remainder of the length. This produced the flow shown in Figure 11.

(ii) shape and size of chip delivery tube

The size of the delivery tube received at our lab had been increased to a point of hindering chip flow (Figure 12). As is well known, high friction particulates like wood chips adhere strongly to the bin and tube walls. A tight delivery tube forces the auger to shear chips at the entrance. An oversize delivery tube results in only a partial flow across its cross section. The chips close to the auger move forward while the chips close to the wall do not move. Due to its rotation, the auger floats on top of the chips, in one of the top corners[10]. Reducing the size of the delivery tube helps reduce this effect. The delivery-tube cover is bolted to the tube. Removal would be facilitated if these bolts were replaced by snap-off fasteners for quick access.

(iii) increased overall length of the installed appliance

One of the features of this bin is the fact that it is installed lengthwise with respect to the combustion chamber rather than at 90° as the regular bin. In certain installations this might be an advantage whereas in others, it might be a major disadvantage.

(iv) formation of rat holes with sawdust

Whereas chips fed reasonably well with this new bin, sawdust rapidly bridged and formed rat holes and fuel delivery stopped after a very small portion of the bin

[10] Looking at the auger from the end, it tends to go to the corner indicated by the direction of rotation of the top of the auger.

emptied. After examination of the conditions under which this bridging occurs, we doubt that reducing wall friction would influence flow enough to make the change worthwhile.

(c) Effect of design modifications

(i) power requirements

There was no net effect; the increased chip shearing offset the removal of the mixing mechanism.

(ii) cost of materials and fabrication

If the desired auger flights were readily available, this bin would be easier to fabricate. It also does not require a complex adaptor to connect the delivery tube to the shape of the bin. It does not require a mixing mechanism with a costly wheel, large shaft, triangular mixers and two large bearings with their supports.

(iii) frequency of blockages

As delivered, this bin blocked frequently. With the modifications that were made, its performance with chips was much the same as that of the normal bin supplied with the Bioblast.

Figure 10. Alternative bin design: this bin design was submitted to the manufacturer as an alternative to the "normal" bin presently used with the Bioblast.

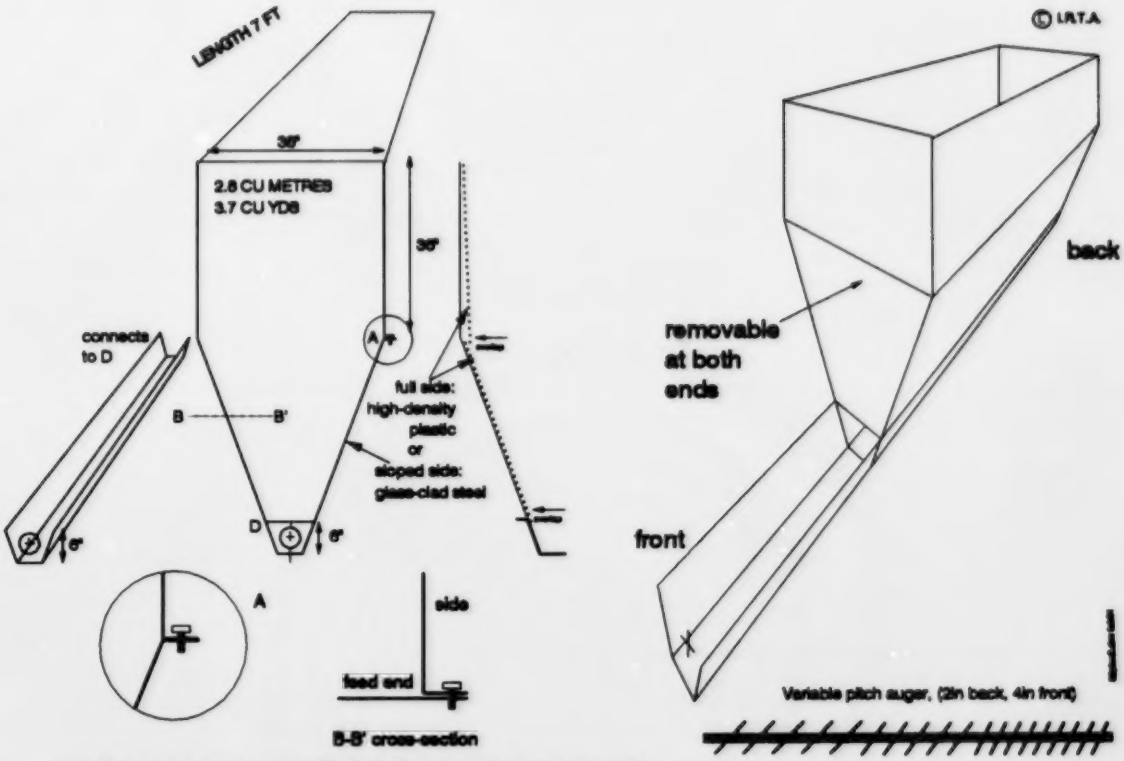


Figure 11. Auger problems with new bin

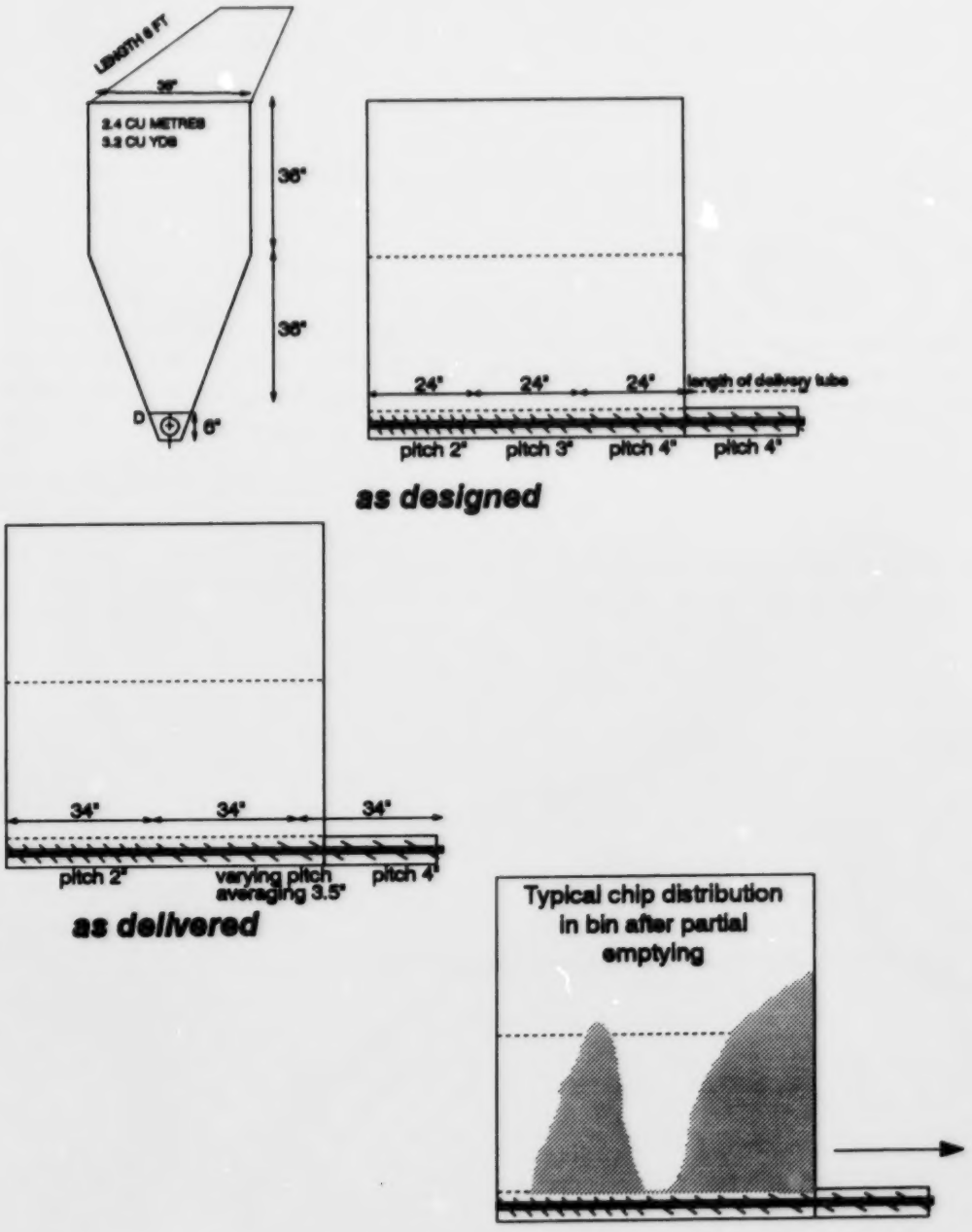
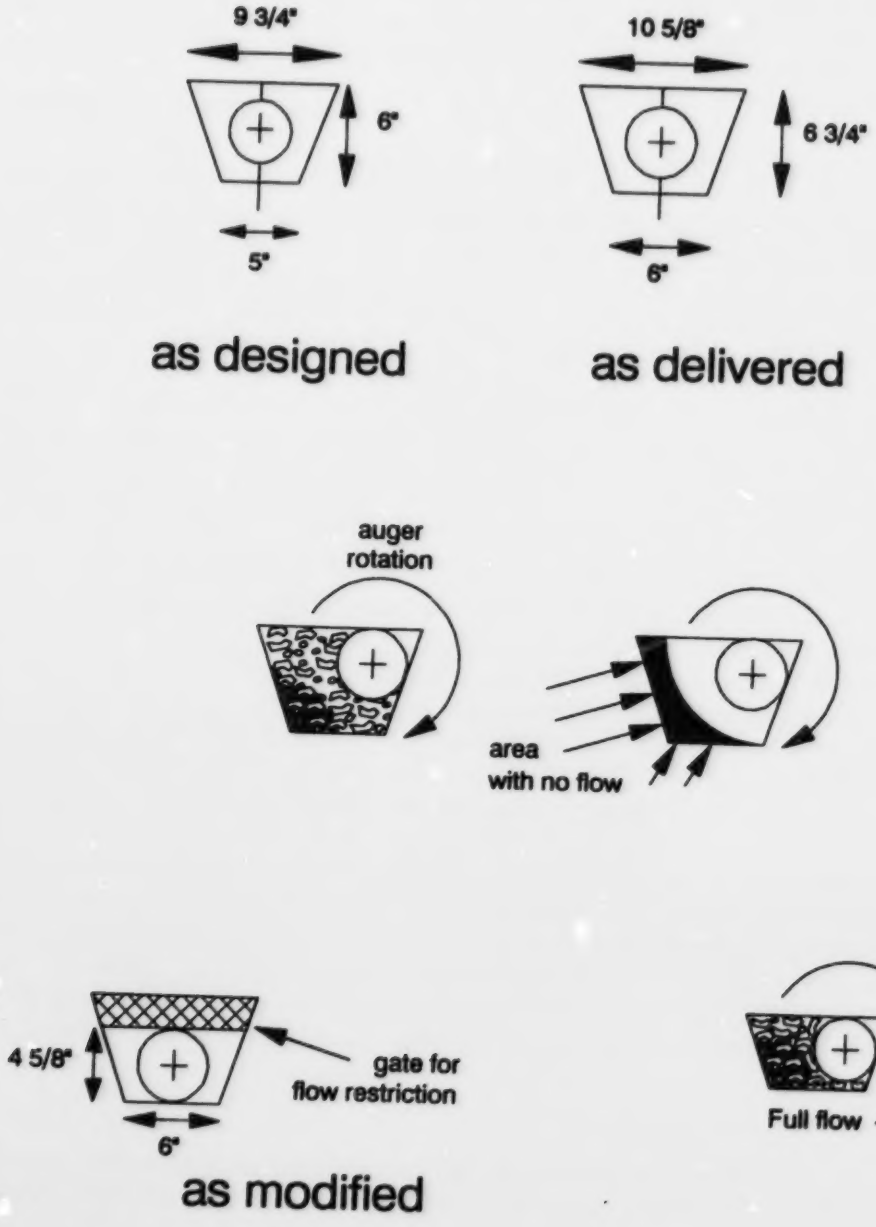


Figure 12. Chip delivery tube problems with new bin



6.4 Safety considerations

6.4.1 Burnback protection

In this appliance, dry chips (below perhaps 25% mcwb) will burn back towards the bin. This burn back is stopped eventually, when the heat sensor turns on the douser. The incidence of burnback can be reduced by making sure the cover is always tightly shut and the bin is kept full.

6.4.2 Appliance wall temperatures (exterior surfaces)

Because of the high temperatures recorded on the outside surfaces of the bottom of the combustion chamber, the installation must rest on an incombustible surface. Because of the high temperatures recorded on the outside walls of the combustion chamber, a sheet metal radiation shield with air space should be installed around the appliance for supplementary protection.

7.0 DISCUSSIONS OF BIOBLAST TEST RESULTS

7.1 Emissions

The 90 kW Bioblast-2 demonstrated that it is capable of burning chips and sawdust at a variety of moisture contents with low emissions. At low burn rates emissions from both wet chips (46% mcwb) and dry sawdust rose sharply.

7.2 Storage bin and fuel feed

Basic fuel feed problems were identified with the Bioblast. The promising research done on chip transport for small systems[11] has not been incorporated into the Bioblast. Efforts should be made to apply some of this research whenever circumstances justify.

Apart from these concepts, the manufacturer must realise the importance of quality control (filing, smoothing, alignment) for all components along the chip path. Clean transitions between components and adequate clearances between fixed and moving parts can minimize fuel blockages, aggravation and loss of time. Design modifications to some of these areas could remedy these problems.

7.3 Efficiency

Two factors influence efficiency. The first, jacket loss from both the preheater combustion cell and from the heat exchanger accounts for almost 14 percentage points. If the appliance is operated in an environment which needs to be heated, the jacket loss is used for space heating, reducing the real loss of efficiency. Alternatively, a heat pump system can be used to transport the heat to an area which requires space heat. The use of insulation to reduce radiation loss from the combustion chamber will increase the amount of heat transferred to the boiler. Insulating the top plenum on the boiler will not increase efficiency but will increase chimney temperature, which may be useful in many situations.

The second factor relates to the combustion air supply. Efficiency is improved if the amount of excess air required for clean combustion is reduced. This can be done by adjusting the combustion air supply to a minimum to obtain the highest possible reading on the CO_2 meter, while maintaining a low CO level. On this appliance, a CO_2/CO ratio of more than 10 is easily attainable. If no instruments are available, using the technique described in section 6.1 will provide similar results. Further design improvements by the manufacturer

[11] Data gathered by Bruce McCallum on pendulum augers and work by BC Research Council on the non-compacting feeder and other types of feed systems still have to be applied to small combustion systems.

might lower combustion air requirements and increase total efficiency while reducing emissions.

7.5 Safety

There are several items that should be addressed regarding safety.

i- The preheater can be operated while bin cover is open. It could remain open by accident or by carelessness. This can lead to burnback when the fuel level gets low. Since an interlock mechanism would make the situation worse by stopping fuel feed[12], we recommend that the cover be wired so that a red warning light on the control box is activated when it is open.

ii- The surfaces of the combustion chamber reach very high temperatures and should be guarded with a simple sheet-metal radiation shield.

7.6 Materials

If the power of the combustion air blower is increased, higher burn rates might be attained. Some of the combustion cell materials might not be adequate for the higher temperatures generated.

7.7 Installation/operating instructions, schematics

No instructions whatever are provided with the unit. This deficiency should be remedied immediately.

A complete set of electrical schematics **must** also be made available. The instruction booklet should include original data sheets and instructions for such components as timers, relays, etc. Heating equipment breakdown must be urgently repaired by **local** electricians. In a previous report on stokers and preheaters, we criticized this aspect of European-made components. For a greenhouse operator, a Canadian manufacturer is just as far away on a weekend as a European manufacturer.

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[12] Burnback is more likely to occur when the auger is not moving fuel forward.

Appendix 1

Bioblast 2 data sheet

Maximum output for prolonged use, with hardwood chips : 324 MJ/h or 90 kW

Recommended fuels:
screened chips (no long slivers)

Recommended moisture content:

chips between 20 and 40% mcwb
sawdust between 20 and 40% mcwb

not recommended for fuels over 45% mcwb
not recommended for very dry sawdust (below 15% mcwb)

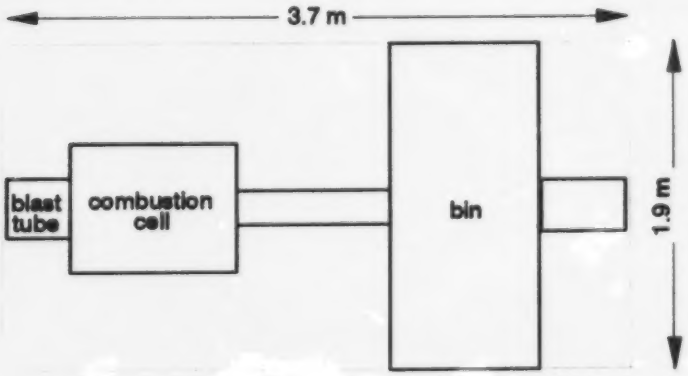
Appliance should be installed on a non-combustible surface.

Electrical requirements:

220 volts AC, 15 amps.

Size: floor area, without heat exchanger (i.e. boiler or hot air)

Floor plan



Appendix 2

Pressure loss across the Parrsboro boiler:

data provided to the designer and manufacturer.

Comb #	dry kg/h	draft kPa	gas temp C	delta P Pa	CO2 %	CO %	O2 %
2366	11,58	0,090	93,00	0,050	7,39	0,01	13,42
2365	15,32	0,100	87,38	0,050	11,69	0,27	8,82
2368	12,65	0,085	#N/A	0,040	7,50	0,02	13,24
2371	15,41	0,100	109,00	0,025	9,73	0,04	10,89
2370	18,79	0,110	#N/A	0,010	11,60	0,08	9,10
2369	22,99	0,120	125,58	0,020	13,24	0,20	7,31
2375	12,17	0,070	91,00	0,085	12,26	0,52	7,47
2372	15,22	0,100	105,00	0,005	8,73	0,02	11,64
2374	18,22	0,090	104,00	0,075	14,95	0,49	4,72
2373	23,18	0,100	110,00	0,070	16,20	0,83	3,66